Appendix 1

Imaging Methodology

This book focuses primarily on the topographical features of human bone. To adequately convey this information through images, we endeavored to minimize the confusing and unnecessary aspects of natural bone material, such as stains and the translucence of some bones and teeth, and to concentrate on the important morphological features. Preparation of the bone, imaging equipment, lighting and staging, media, and post-processing were each significant variables in meeting these goals.

A1.1 Photography

A1.1.1 Preparation of the Bone

Osteological material was coated in such a way that stains and glare were reduced without loss of surface details. After the bone material was degreased, a finely ground, opaque titanium pigment suspended in a solution of ethylene glycol and water was applied through the nozzle of a 0.2 mm double-action airbrush. Air pressure was adjusted between 24 and 40 PSI during application, depending on a variety of circumstances including the nature of the bone surface and humidity. One coat was generally sufficient to obscure stains and create an opaque nonreflective surface.

Other methods of coating, including ammonium carbonate smoking and direct brushing with a variety of paints, proved unacceptable. The titanium coating used was easily removed with water and/or alcohol.

A1.1.2 Equipment

Cameras used to record the images included a Sinar F2 4 × 5 view camera, a Hasselblad 500CM (medium format), and a Nikon F3T (35 mm format). The use of three formats allowed similar proportional enlargements of the negatives regardless of subject size, because subject-to-image ratios could be kept somewhat the same. This resulted in a fairly consistent grain character for each figure. The primary 4 × 5 lens was a Schneider Symmar HM 240 mm f/5.6 with a Copal #3 shutter. A 120 mm f/2.8 Zeiss S-Planar with a B55 extension tube provided the images in the medium format, and a 55 mm f/2.8 Micro-Nikkor with a PK-13 extension tube worked on the tooth shots in the 35-mm format.

A few images new to this edition (phalangeal bases for example) were shot digitally from the original source material with a Nikon D2xs and 35–70mm f/2.8 Nikkor lens.

A1.1.3 Lighting and Staging

Lighting was exclusively artificial (daylight-balanced). Two Speedotron® electronic strobe packs at full power were used to drive one quad head (4800 watts) main light and one single head (2400 watts) background. Each strobe was raw (without reflector or diffusion).

Staging began with a 4×8 foot neutral gray sheet of formica on the floor. An 18×24 inch sheet of nonglare glass was suspended about 16 inches over the background on two C-stands. Several sheets of white foam core board formed a tunnel through which the background strobe flashed. An additional board acted as a bounce reflector at the end of the tunnel. The only outlet for background light was through the glass stage from below. To maximize surface detail, the main light flashed at a very low angle to the subject. This light bounced off of a white card on the opposite side of the subject to fill in shadows and reduce contrast.

Each bone was placed on the glass and oriented on a variety of pliable and tacky substances hidden from view. In most cases, the angle and power of the flash created a slight reflection of the subject on the glass. To absorb excess light and minimize this effect, a black mask was cut for most subjects and placed out of view on the underside of the bone.

The direction of light and subject orientation follow traditional scientific illustration convention. In general, the light falls on the subject from the upper left relative to the viewer. Within this reference a hierarchy is followed for the preferred orientation: dorsal top, ventral bottom; proximal up, distal down; anterior left, posterior right; superior up, inferior down; and any special view required to convey specific information. Lateral views are left lateral where bilateral symmetry exists. All skull part figures are oriented in approximate Frankfurt Horizontal with the aforementioned conventions in mind. Any deviation from these conventions is mentioned in the figure legends. All bones were photographed complete with one exception. The femur was too long to fit on the stage and was shot in two parts.

A1.1.4 Film and Development

Ilford FP4 black-and-white film (rated ISO 125) was chosen for its moderate contrast, wide latitude, availability in all formats, and fine-grain characteristics. Preliminary tests indicated that an ASA of 80 worked best for the high-key subjects of the project. Polaroid instant films type 55 and 554 were employed to check contrast, lighting, depth of field, and orientation before most final exposures.

Because extension tubes and long bellows extensions were used in most shots, depth of field (focus) became a concern. Thus a near-minimum lens aperture was used whenever possible to balance sharpness with depth of field. A slower film speed would have required a very close and difficult-to-control flash-to-subject distance. Also, the additional fine grain available from the slower films, though desirable, was superfluous because of the limitations of photolithography and the printing process.

All film was developed normally. The images were enlarged to produce prints at natural size of the subject bone. We made separate prints of each end of the longest bones that required splitting the images to fit on a page at natural size. Most images were printed on Ilford Polycontrast resin-coated paper with #4 and #4.5 filters. Some photographs were printed on Ilfobrom fiber-base paper, contrast grade 3. Certain areas of each image were burned with no filter to bring out highlight detail; other areas were dodged to open shadows. The prints were slightly overexposed to avoid loss of texture in the highlights and to carry all the detail evident in the negative. This artistic compromise maximized the educational content.

Main light-to-subject distance remained largely constant. The camera-to-stage distance varied in some cases to maintain a consistent film plane-to-subject focus distance as the size of the subject changed. Certain deep subjects (*e.g.,* proximal views of limb bones) dictated adjustments that resulted in great camera-to-stage distances. These greater camera-to-stage distances led to unavoidable variations in lighting ratios between the main and background lights. Since the background

is superfluous to the intent, we printed the figures to maximize the information on the bone and allowed the neutral dark gray background to vary as much as one-and-a-half gray scale zones.

A1.1.5 Scanning and Photolithography

For the original edition of this book, halftone screens were created from the photographic prints. In the second edition, digital encapsulated postscript files were used in "direct to plate" printing, as is the case for the present edition. A few figures new to this edition featuring non-split long bone images were re-scanned using a Microtek ArtixScan 1800f directly from the original negatives to avoid the inconsistencies of matching the ends of split prints used in the core of the book. These images were processed in Adobe® Photoshop® CS3.

A1.1.6 Post-processing of Digital Images

For the current edition of this book, the tonally variant backgrounds of the original photographic prints were digitally isolated and set to digital black.

For each image, the background was digitally isolated using Adobe® Photoshop® CS3. A coarse level of background selection was initially accomplished using Photoshop's Quick Selection Tool with a 10-pixel brush on the image at 100% magnification. Then, while viewing the image at 300% magnification, and with a 5-pixel brush, the selection area was manually edited to include all background areas in the photograph and to ensure that no portions of bone or photographic scale were included in the selection area. Finally, the magnification was increased to 600% and final touch-up was done with a 3-pixel brush and the Elliptical Marquee Tool.

Using the Refine Selection Edge Tool with the radius set to 0 pixels, contrast set to 10%, smooth set to 0, and feather set to 0.5 pixels, the selection was set to contract (away from the bone and other subject matter) by 15%. Before applying the selection refinement, the selection was viewed as a Quick Mask, toggling back and forth between the mask and the image to visually verify the boundaries of the refined selected area. While setting the selected area to contract by 0% would have a more visually pleasing result, contracting by 15% was selected as a safety factor to ensure that not even the slightest portions of the edges of bones would be accidentally selected.

As a final step, a new layer was created and superimposed on the image layer. With the foreground color set to digital black, and with a brush size set to 2500 pixels, the refined selected areas of background were painted digital black in the superimposed layer. After a final visual inspection of the result, the dual-layer image was archived. A flattened (single-layer) copy of each image was produced for inclusion in this volume.

For a few non-critical images of bones, we resorted to creating clipping paths around the subject(s) to drop out backgrounds in the original image. These files were then placed in image frames with a consistent background. This technique was also used to reduce gaps between subjects in one photograph and align them in the final image to fit better on the printed page.

A1.2 Micro-computed Tomography

The bone cross-sections illustrated in Chapters 8, 9, 10, 12, 13, and 14 were obtained through high-resolution peripheral quantitative computed tomographic (HR-pQCT) scanning. The bones were scanned on December 10–11, 2009, by Andrew Burghardt of the Musculoskeletal Quantitative Imaging Research (MQIR) Group of the Department of Radiology and Biomedical Imaging at UC San Francisco, using a Scanco Medical XtremeCT HR-pQCT scanner. The scanner has an isotropic resolution of 41 μm (*i.e.,* voxel size of 41 μm^3). The exact locations of the sections were indicated by single, short, light pencil marks executed with soft lead (the resolution of

the machine rendered the use of even the thinnest Teflon ribbon or PTFE tape problematic).

The bones were placed on a carbon-fiber plate and oriented according to anatomical and biomechanical conventions using radiotranslucent foam. Once properly positioned, the bones were firmly fastened to the carbon-fiber plate using 3M Micropore™ adhesive tape. The portions of the adhesive side of the tape that were closest to the bone were covered by short, reversed segments of the same tape, such that no adhesive touched the bone. The carbon-fiber plate was positioned inside a carbon-fiber specimen tube which was then placed into the gantry of the scanner. The plate was then leveled using a bubble level. The position of the tomographic acquisition was aligned with the desired section location using a laser alignment beam. The scanner then scanned a 9 mm section of the bone, centered on the desired section.

Raw data were gathered by an array of three 1024×256 charge-coupled devices (CCDs), and were subsequently reconstructed using a modified Feldkamp algorithm across a 3072×3072 matrix with 16-bit color depth.